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Quarterly Progress Report

Division 4

Radar

15 September 1964

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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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INTRODUCTION

This report summarizes the General Research activities of Division 4 during the period 1 June through 31 August 1964. The major portion of the Division's activities is devoted to PRESS, Radar Discrimination Technology, BMRS, Space Communications, and Project Apollo. Therefore, all the work of Group 41 and the majority of the work of Groups 42, 43, and 45 is described in separate reports. Detailed reports of research are available in Technical Reports, Group Reports, and Journal Articles.

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Head, Division 4

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15 September 1964

Accepted for the Air Force
Franklin C. Hudson, Deputy Chief
Air Force Lincoln Laboratory Office

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356	Limitations of Oxide-Cathode High Current Density Operation	H. A. Pike	22 May 1964	DDC*

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1972	Superconducting Resonant Cavities	E. Maxwell	Progress in Cryogenics, Vol. 4 (Academic Press, New York, 1964)

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† Reprints available.

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* Author not at Lincoln Laboratory.

† Division 6.

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* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

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RADAR SIGNAL PROCESSING
GROUP 42

I. INTRODUCTION

Group 42 presently supports four Laboratory projects: PRESS, Radar Discrimination Technology, Apollo, and Haystack.

The PRESS and Radar Discrimination Technology activities are described in Semiannual Technical Reports to ARPA, and the activities on Apollo are recorded in bimonthly progress reports to NASA. A summary of the work on Haystack instrumentation is given here.

II. HAYSTACK INSTRUMENTATION

A. Antenna Control Generator

The antenna control generator and antenna/computer interface equipment have been operating almost continuously during this quarter. The Dichotron handwheel encoders, which had been a major cause of trouble in the equipment, were replaced with Baldwin encoders, and operation is now satisfactory.

B. Range Encoder and Tracker

Final checkout of the range encoding and tracking equipment will take place after the sequential doppler processor and monopulse angle estimator are installed at the Haystack site in late September.

C. X-Band Distance Measuring System

Work has continued on the ground-based electronics associated with the X-band antenna contour measuring equipment. In its present form, provision has been made for differential distance measurements from the secondary reflector to either of two points on the edge of the primary reflector. Results obtained with this experimental equipment should indicate what steps to take in designing the final system.

D. Sequential Doppler Processor

The sequential doppler processor (SDP) has been completely checked and will be delivered to the Haystack site in late September.

E. Monopulse Angle Estimator

Construction of the monopulse angle estimator is complete and testing of the system is under way. Delivery to the site will coincide with the SDP delivery.

F. Test Signal Generator and Target Simulator

Shipment of the test signal generator and target simulator to the Haystack site has been delayed to allow for the incorporation of certain modifications which were found to be needed for some planetary tracking operations. These modifications have now been completed, and final testing and shipment will take place during the next quarter.

TRANSMITTERS
GROUP 43

I. INTRODUCTION

The principal activities of Group 43 in the research and development of radar transmitter techniques and the study of Air Force range instrumentation radar problems are supported by the BMRS program and are described in the quarterly reports of that program.

II. HAYSTACK HILL TRANSMITTER EQUIPMENT

The installation and testing of all the CW ground equipment was completed as of 10 July 1964. Final tests demonstrated essentially all the features specified for the equipment at the 1-Mw DC and 25-kw CW RF levels. The equipment has been turned over to Group 31 personnel for operation.

The series beam switch regulator intended for use in pulse modulation of the transmitter requires some debugging, which will be done by the Energy Systems, Incorporated, project engineer.

ARRAY RADARS
GROUP 44

I. 900-Mcps TEST ARRAY

Sets of transmitting array antenna patterns were taken both with and without the module power amplifiers. Reasonable agreement between measured and calculated patterns was obtained in both cases.

II. S-BAND SUBARRAY DEVELOPMENT

A. Test Facility

Installation of the subarray antenna pattern testing facility was completed during this period. Major spurious paths between the antenna under test and the test horn were eliminated.

B. High-Power Phasers

A variation of dielectric constant with temperature of the dielectric coolant gave a marginal insertion phase tolerance in the present ferrite phaser design. Therefore, General Electric's efforts have been directed toward using boron nitride as the cooling medium. The boron nitride machines well and serves also as an excellent helix form. Four such phasers will be constructed for parameter tracking tests during the next quarter.

C. Connections and Cabling

Most of the special connector designs for improved matches and dense packaging have been completed. Assemblies of lots (typically 20) for the subarray are under way. Cutting semi-rigid cables to precise lengths is being investigated.

D. Waveguide Power Divider

An in-line dielectric coax-waveguide transition developed by Microwave Development Laboratories has been successfully tested to 200 kw, and Microwave has completed the waveguide divider.

E. Time Delay

The acquisition of a time-domain reflectometer has significantly aided the investigation of transmission media, turns and bends, and interconnections. A foam-supported strip medium, connectors, and diode switches have been selected for the initial fabrication of the time delay during the next period. Ferrite switch study efforts have been increased to find a better high-power switch for time delays than afforded by diodes.

III. GENERAL FERRITE PHASER STUDIES

A computer program has been written to establish theoretical performance of various remanent phaser configurations. Reasonably good initial experimental confirmation has been obtained. Optimization studies are continuing.

IV. MUTUAL COUPLING STUDIES

The program for computation of the effects of mutual coupling on the performance of planar arrays of short and $\lambda/2$ dipoles with and without ground plane has been completed. Extensive data have been collected for the gain and impedance variation of the center element in 7×9 linearly polarized arrays. A report covering the available data is now being prepared. In the future, a computational program will be undertaken to determine the effects of mutual coupling in circularly polarized arrays of dipoles.

Experimental measurements of the impedance variation with scan angle of the central elements in a 10×10 dipole array above a ground plane are under way. The central 8×8 section of the array is driven with a planar, Butler beam-forming matrix while the outer elements are terminated with 50-ohm loads. Correlation of the measured data with computed data for the few cases considered so far has given very good agreement.

V. MULTIPLE-BEAM-FORMING STUDIES

The final report on the analysis of the series-feed multiple-beam former (Blass) is essentially complete. A series of additional bandwidth vs efficiency cases has been run on the computer to fill out earlier results.

RANGE MEASUREMENTS
GROUP 45

I. INTRODUCTION

The principal activities of Group 45 are under the Program in Radar Discrimination Technology (RDT) and are reported in the Semiannual Technical Summary Reports to ARPA of the RDT Program.

II. MILLIMETER-WAVELENGTH SYSTEMS

The millimeter-wavelength systems project affords the opportunity for experimental equipment development, for the study of millimeter-wavelength space communications, and for research in radar and radio astronomy. Work under these headings has been described in detail in previous quarterly progress reports. The project now consists solely of tasks in radiometry and radio astronomy.

A. Millimeter-Wavelength Radio-Astronomical Observations

The radio sources observed regularly during the past quarter were Venus and the Moon. Since the inferior conjunction of Venus occurred during the quarter (19 June 1964), the planet was observed whenever equipment malfunctions or weather did not interfere. Temperature measurements were made at a number of frequencies in the millimeter-wavelength region by Lincoln Laboratory and M.I.T. Research Laboratory of Electronics (RLE) personnel. These measurements are intended to detect the phase dependence of Venus' temperature (Lincoln Laboratory) and possible anomalies attributable to water vapor in the Venusian atmosphere (RLE). The results of the studies will not be known until computer data reduction is accomplished. The Lincoln Laboratory measurements will continue into the next quarter.

The moon was observed at three- to five-day intervals throughout a lunar month (lunation) during this quarter. These observations were made by RLE personnel for two reasons: first, their estimate of the antenna gain will be based on the measurement of the lunar temperature over a lunation; second, they sought to measure the polarization properties of the moon's thermal radiation in order to estimate the dielectric constant of the lunar surface. This latter effort has proven to be difficult, since the present receiver configuration does not measure the difference between two polarizations, but rather requires the difference to be deduced from scans taken at different times. The pointing inaccuracies of the antenna mount seem to produce effects which obscure the polarization effects. Work has begun on converting the receiver for instantaneous polarization measurements.

B. Atmospheric Studies

Since radio-astronomical observations must be taken through the atmosphere, a knowledge of the atmospheric attenuation is requisite for accurate measurements. During this reporting period, a study was made of the various methods by which one can estimate its opacity (zenith attenuation). These methods involve the following measurements:

(1) Attenuation of sunlight on a water-absorption line in the infrared region
(2) Temperature of the atmosphere as a function of elevation angle
(3) Temperatures of the sun and moon while they are rising or setting
(4) Meteorological data using weather balloons.

Completion of the analysis and correlation of the data await computer reduction of some of the sunset data.

C. Pointing Studies

The high angular resolution of the 28-foot-diameter antenna at millimeter-wavelength frequencies necessitates a sound knowledge of the pointing accuracy of the system. During the previous quarter a thorough study was made of the servo errors, thermal effects, pointing references, and axis tilts. This study indicated that simple corrections could be applied to the pointing calculations to compensate for the antenna-mount errors. During the present reporting period, more pointing-error data were taken. It now is clear that no simple model accounts for all the errors observed. Further tests were initiated to determine if detailed mapping of errors in a small region of the sky would allow corrections to be applied to sources passing through such regions. This latter approach seems promising, but more data must be taken before results are conclusive. Should this method prove usable, a study of the strong radio sources will be initiated during the next quarter.

MICROWAVE COMPONENTS
GROUP 46

I. INTRODUCTION

Group 46 contributes to the radar program through direct participation in specific projects, and through a program of general research which is closely related to the microwave requirements arising from radar projects. Contributions are made to the General Research Program through the support of Haystack Hill, operation of a high-power microwave laboratory, development of low-noise receiver techniques and receivers for space communications, and studies of very-high-gain antennas.

II. HAYSTACK HILL MICROWAVE COMPONENTS

A. 7750-Mcps Transmitter

The design and construction of the VA-879, 100-kw transmitter are virtually complete, and the system is undergoing initial tests. The VA-879 klystron has been tested at a low-level (25-kw) output with satisfactory results. A second Varian Associates' VA-617 driver TWT has been delivered.

The experimental development of the balanced, transistorized arc detector is complete. The design of a fully shielded and mechanically engineered version is in progress.

B. Feed Horn and Circular Polarizers

All parts for the multimode feed horn have been obtained and assembled with the circular polarizers, orthogonal mode transducers, and hybrid networks. Using a circularly polarized source, measurements have been made of the radiation patterns of the primary feed. Measurements have also been made of the primary feed gain and the VSWR. These data will be presented in a forthcoming report.

C. Low-Noise Receivers

Two low-noise receivers will be used in the initial Haystack Hill radar experiments. Each will consist of a cascade of two parametric amplifiers that will be cooled in dewars to either 77.4 or 4.2°K. The first of these units is being checked out with the final pump circuitry. At room temperature, the two-stage cascade has yielded a 300°K noise temperature with a gain of 26 db and a bandwidth of 59 Mcps. At 77.4°K, a noise temperature of 100°K has been achieved with a gain of 26 db and a bandwidth of 30 Mcps.

The pump circuits, IF amplifiers, noise temperature monitor, and other auxiliary equipment have been installed and tested in the receiver racks. A new dewar with twice the operating "hold time" of earlier units has been delivered.

Work has continued on the electroformed parametric amplifiers that will be operated in a closed-cycle refrigerator. Two of the electroformed units have been completed and successfully tested at room temperature.

D. Noise-Rejection Filters

Construction of the experimental, high-power 8050-Mcps noise-rejection filter has been completed. Low-power tests showed the rejection was greater than 60 db over an 8.5-Mcps band centered at 8050 Mcps. At the pass-band frequency of 7750 Mcps, the attenuation of the filter was 0.025 db and the VSWR was 1.055. High-power tests at 7750 Mcps showed the filter to be capable of operating indefinitely at a power level of 150-kw CW. At 175-kw CW, arcing occurred along the center of the main waveguide.

The measurements show this type of filter to be practical for use in the Haystack Hill radar high-power line. It was observed that RF heating of the resonators was sufficient to move the center of the rejection band by about 6 Mcps. This additional bandwidth has been designed into a high-power 8350-Mcps noise-reject filter using six pairs of resonators and a high-power 8050-Mcps noise-reject filter using four pairs of resonators.

E. RF Transmission Package

The first 100-kw circulator (Model CHX 26) was delivered by the Raytheon Company on 1 July. The reoccurrence of corrosion in the input cast hybrid and bend assembly necessitated the replacement of the assembly. The circulator is now being incorporated into the RF box. A second Raytheon circulator, which was found to have defective solder joints, is now being rebuilt by Raytheon.

It is anticipated that the assembly and testing of the complete RF transmission package will be completed early in September.

F. Waveguide Gaskets

Two X-band waveguide gaskets have been developed which are more suitable for high-power operation than presently available commercial gaskets. These gaskets are fabricated from annealed copper. Further information will be presented in a Group report.

III. STUDY OF SURFACE RESISTIVITY OF MICROWAVE COMPONENTS

The purpose of this study is to investigate methods of minimizing power losses and noise temperatures by appropriate treatment of the surfaces of microwave components. During this quarter, effort has been directed toward the life testing of the following coatings: (a) chromate (iridite process), (b) silicone, (c) gold immersion (applied by electrodeless chemical techniques), (d) gold immersion over nickel immersion, (e) gold immersion over silver immersion, (f) gold flash, (g) silver flash, and (h) rhodium flash over electroplated silver. The first two phases of the life test have been completed. The first phase consisted of cycling samples through a 149°F and 98-percent relative-humidity environment during the day and a 275°F low-humidity environment during the night for a period of 36 days. The second phase consisted of exposing the samples to outside weather conditions for 30 days. The results of the first phase are available; the data from the second phase are currently being reduced.

An interesting side experiment resulting from the study of surface resistivity involved a determination of the relative permeability of nickel at X-band. The relative permeability was measured at 7.567 Gcps and found to be approximately 5.50. This number is in close agreement with a value extrapolated from work by W. Arkadiew.*

IV. SOLID-STATE AMPLIFIERS

A. Cooled, Varactor-Diode Amplifiers

Modifications have been made to a prototype L-band parametric amplifier in order to further isolate the idler from the signal circuit and to facilitate the adaptation of the amplifier to a cryogenic environment. These changes are now being incorporated into the pilot production run of L-band amplifiers. Upon completion of the modifications, a mock-up of the AMRAD receiver system will be assembled and tested.

B. Wide-Band, X-Band Parametric Amplifiers

Electrical tests have been made on the wide-band, X-band, quasi-degenerate amplifier. Amplification was observed over a 2-Gcps range but with large variations in amplitude because of insufficient diode pumping. The diode pumping problem resulted from the fact that the signal circuit propagated pump power in higher-order modes. This diverted pump power from the diode and also made it impossible to adequately pump the diode without the occurrence of low-frequency oscillations. This is a fundamental problem and relegates the type of construction used with this amplifier to lower frequencies such as L- or S-band where higher-order modes are more easily suppressed.

Consideration is now being given to a nondegenerate, wide-band, X-band parametric amplifier that will utilize more or less conventional construction, except for the broadbanding resonator. This resonator will be a half-wave section of low-impedance coaxial line with the center conductor slotted in the manner of a waveguide waffle-iron filter in order to suppress the pump and the idler in any mode.

C. Diode Measurements

Effort has continued in the measurement of diode parameters at S-band with the triaxial diode holder. The InSb varactors, which were mentioned in the last quarterly progress report, exhibited very favorable characteristics, but during the interim have either opened or shorted. These diodes have been returned to the supplier for further study.

Tapers and diode holders in four waveguide sizes in the frequency range from 8 to 40 Gcps have been fabricated with resulting VSWR's of 1.10 or less. Transmission-loss and return-loss measurements are being made on typical diodes. An attempt will be made to relate the results of these high-frequency measurements to packaged-diode element values and equivalent circuits.

D. Cryogenic Temperature Control

Investigation has revealed that the temperature field within a dual-dewar system is such that the temperature of a diode holder may be controlled by varying the distance between the holder and the fluid surface in the inner dewar. With liquid helium in the inner dewar, it was

* W. Arkadiew, "The Disappearance of Ferromagnetic Properties for Very Short Electrical Waves," Physik. Z. 14, No. 13, 561-62 (July 1913).

found possible to maintain the diode holder at any temperature in the range from 4.2 to 200°K by manual control of the holder position. An automatic temperature control system has been designed and is under construction.

E. Microwave Transistors

Two types of transistors show promise of providing gain at frequencies up to 10 Gcps. One of these is the metal base transistor (MBT), and the other is the surface controlled avalanche transistor (SCAT).

Both devices make use of high-energy electrons as current carriers in order to reduce the transit time and thus improve the high-frequency response. These devices are in the early stages of development, and no units are available for study here at Lincoln Laboratory. It does appear, however, that there is the possibility of a major breakthrough in the development of four-terminal semiconductor amplifiers at microwave frequencies, and progress in this area should be closely followed during the next few months.

F. Cooled Transistors

Theory predicts a direct relationship between the noise temperature of an amplifier and its ambient temperature if all other parameters remain constant with temperature. An effort has been made to verify this theory by cooling some Texas Instruments, Inc., 2N2996 transistors in liquid nitrogen at 77.4°K. These transistors were chosen for the experiment because their characteristics appeared to show less deterioration at 77.4°K than those of most other transistor types. It was found that while the predicted temperature dependence of the transistor noise temperature was valid, the deterioration of the transistor parameters, particularly the DC value of the current gain (α_{DC}), more than counteracted the improvement due to the reduced ambient temperature. Recently published collector characteristics for the metal-base transistor strongly suggest that the α_{DC} of the MBT does not degrade with a reduction in the ambient temperature to 77.4°K. If the full high-frequency potential of the device can be realized, there will be a real possibility of developing a low-noise microwave transistor amplifier.

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13. ABSTRACT

This report summarizes the General Research activities of Division 4 during the period 1 June through 31 August 1964. The major portion of the Division's activities is devoted to PRESS, Radar Discrimination Technology, BMRS Space Communications, and Project Apollo. Therefore, all the work of Group 41 and the majority of the work of Groups 42, 43, and 45 is described in separate reports. Detailed reports of research are available in Technical Reports, Groups Reports, and Journal Articles.

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